Wearable Robots Help With Stroke Rehabilitation

A new generation of robotic devices may one day give thousands of stroke patients a speedier recovery by helping them to regain the ability to move their arms normally. Strokes afflict 700,000 Americans annually, frequently leaving partial paralysis in their wake. One of the most common stroke disabilities is a paralyzed arm. Conventional rehabilitation requires physical or occupational therapists to spend long hours with patients, manually helping them as they move the affected arm hundreds or thousands of times. “The movement therapy is beneficial but very labor intensive,” says Dr. Louis Quatrano, program director at the National Center for Medical Rehabilitation Research at the National Institute of Child Health and Human Development (NICHD).

The National Institute of Biomedical Imaging and Bioengineering (NIBIB) and NICHD are jointly funding development of robotic devices that could usher in a new era in stroke rehabilitation. If successful, they will accelerate rehabilitation of patients with paralyzed arms and reduce the cost of physical therapy. Researchers plan to equip the devices with sensors and actuators that help patients repeat movements on their own. This would allow people to continue practicing the newly relearned movements outside physical therapy sessions. The new robotic devices will be worn like arm braces or orthopedic casts.

“There was preliminary evidence suggesting these robotic devices would be useful. The next question was: Can we implement this type of device so patients will have access to it?” Dr. Quatrano says.

A Wearable Robot

Two research groups jointly funded by NIBIB and NICHD are developing the devices. One group has developed a prototype of an upper extremity robot powered by “pneumatic muscles,” which are devices that mimic the movements of muscles. Led by Dr. JiPing He, a bioengineering professor at the Biodesign Institute of Arizona State University, the group developed a robot to train patients in critical movements, such as those used in reaching and eating. The device will help patients to increase the abilities of joints involved in tasks such as raising the arm, flexing the elbow, and rotating the forearm.

A robotic device (The Hand Mentor™) helps people improve their hand function following a stroke. *Photo courtesy of Kinetic Muscles, Inc., of Tempe, Arizona*

One of the major design challenges Dr. He’s team faced was creating a wearable robot. To lighten the device, the designers discarded the traditional robotic power source – an electric motor – in favor of a pneumatic muscle that mimics the contraction and relaxation of an actual muscle.

“The pneumatic muscle is not as powerful as a human muscle, but will be very easy and safe to use,” says Dr. He.

A compressor supplies the device’s pneumatic power, and the system is small and portable, allowing patients to continue therapy at home. Patients can adjust the force needed to help arm movements based on their previous attempts.

“As patients gradually become better, they can get more voluntary control with less assistance,” says Dr. He.

Testing with stroke patients is expected to begin in early 2005. Dr. He is collaborating with Kinetic Muscles, Inc., of Tempe, Arizona, which already markets a smaller robotic device to help rehabilitate hand function in stroke survivors. NICHD funded development of that device.

Clinical Rehabilitation Device

The other research group jointly funded by NIBIB and NICHD is led by Dr. David Reinkensmeyer, associate professor of mechanical and biomedical engineering at the University of California, Irvine. Dr. Reinkensmeyer’s group is developing a prototype based on a preexisting design, an “antigravity orthosis,” that uses the force from elastic bands to relieve the weight of the patient’s arm. Tariq Rahman of the Alfred I. DuPont Hospital for Children in Delaware originally developed the design. Now, Dr. Reinkensmeyer’s group is adding sensors, developing software, and using pneumatic power to drive the actuators that will help arm movement. Researchers plan to use the device, which is powered by a pneumatic compressor the size of a small microwave oven, in clinical settings. The larger compressor delivers more power to the robotic device than a portable model and allows patients to perform a broader range of movements. Researchers expect to test a wider range of therapeutic strategies with this device, because they can precisely control the force applied by the robot.

Developing the pneumatic power that drives the robotic arm’s precision is a primary challenge facing the researchers. Pneumatics permit a much lighter design than standard electric motors, but such systems are more difficult to control because air is compressible and responds to compression in a nonlinear way. Dr. Reinkensmeyer’s design uses pneumatic cylinders to move the robotic device and a sophisticated algorithm to control the cylinders.

“The device has five degrees of freedom and will accommodate very naturalistic arm movement across a wide range, so you can touch your mouth, reach up to a shelf, or practice a hug. The robot will be smart enough now to assist the patient only as much as they need to fully assist the arm if the person is really weak, or fade away to nothing as they recover,” Dr. Reinkensmeyer says.

References

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